In 1955, this country manufacturer 1,363,241,000 pounds of cheese[1]. Assuming that nine pounds of liquid whey are produced for each pound of cheese, the cheese factories had over 12.3 billion pounds of whey. Of this amount as much as 3.4 billion pounds are presently recovered [2]. Of the 8.9 billion pounds remaining, some is returned to the farms for feeding but much of it is wasted and poses a disposal problem to many of the 1,785 cheese manufacturing plants. When spread among these producers, this figures to about 12,500 pounds of whey per day per plant. This does not take into consideration the whey from 1,700 other plants that produce a half billion pounds of cottage-type cheese annually. (Although the Mountain and Pacific States produce only about 6.5% of the manufactured cheese, they produce 25% of the creamed cottage cheese.)

The main constituents of raw cheese whey[3] are: sugar 4.80%; proteins 0.85%; ash 0.60%; fat 0.34%; water 93.40%. Practically all fat is recovered. The whey represents a renewable annual reserve of about 83 million pounds of protein and 470 million pounds of sugar. The Task Committee on Dairy Waste Disposal reported that 100,000 pounds of whey per day should be available to operate an evaporator economically and that 250,000 pounds are necessary for a spray drier. Collection of the whey from several cheese factories for condensing is done in some areas. Economical haul for fluid whey is about 40 to 50 miles, while for a 30% concentrate it is about 150 miles [4].

All plants have washings to dispose of and many others have a whey disposal problem, as well. Our laboratory has three projects concerned with these problems, two on disposal and one on utilization.

<u>I. Laboratory investigations of a microbiological process for the oxidation of cheese whey in order to establish guides for the practical method for the disposal of whey from cheese plants.</u>

Whey may be stabilized aerobically if the requirements of cell synthesis are satisfied. For example, when whey was discarded by the college dairy into

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* A Laboratory of the Eastern Utilization Research and Development Division, Agricultural Research Service, U. S. Department of Agriculture.

(1) Anon. Production of Manufactured Dairy Products, 1955. USDA, Statistical Bulletin No. 199 (November, 1956).

(2) Whittier, E. O., and Webb, B. H. "By-products From Milk." Reinhold Publishing Corp., N. Y. (1950).

(3) Sanders, M. D. What Can Be Done With Whey? Proc. 3rd Ind. Waste Conf. Purdue Univ. 288-292 (1947).

(4) Eldridge, E. F., Milk Products Waste. In "Industrial Wastes, Their Disposal and Treatment." Ed. by Rudolfs, W. pp. 31-50. Reinhold Publishing Corp., N. Y. (1953).

the 10,000-gallon pilot waste treatment plant at Pennsylvania State University[5] an uncontrollable mucilaginous foam resulted and the plant had to shut down. Treatment could not be resumed until the whey waste from cheese manufacturing was diverted to another sewer. Some months later an unanticipated violent foaming again produced a nuisance. The sanitary engineers made inquiries of the dairymen and learned that a new whey separator was discharging the whey on the floor of the market milk room and thus into the pilot plant. This waste had to be treated. Conditions were corrected by adding 100 lb. of ammonium sulfate per 5000 lb. of whey.

Aerobic biological treatment methods must give serious consideration to nutrition of the microorganisms that synthesize their cells from the wastes while oxidizing a portion. Examination of the composition of dry whey[6] shows 73% lactose and 13.5% protein as compared to 51% and 37% present in dry skim milk. For each 100 units of sugar there is present one-fourth as much protein (and hence nitrogen) in whey as in skim milk.

According to the assimilation equation, 37 units of protein are necessary to produce a stable product with 51 units of sugar yielding 53 units of cell substance.

$$8\,(CH_2O) + C_8H_{12}N_2O_3 + 6\,O_2 \longrightarrow 2\,C_5H_7NO_2 + 6\,CO_2 + 7\,H_2O$$

With an equal amount of whey, the 13.5 units of protein should take care of only 18.6 units of sugar and produce only 19 units of cell. This would leave about 52 units of lactose needing nitrogen.

The nutruitional imbalance can be avoided if the nitrogen content of the waste is known as well as its oxygen demand or its carbon content (carbon x 2.67 = COD). Work done on various types of organic wastes [7] showed that stabilization was obtained when the BOD to N ratio was about 17 to 1, calculating to a COD to N ration of 25 to 1. Skim milk has a COD to N ratio of 18 to 1 as compared to 45 to 1 for whey.

The nitrogen that must be added to whey can be determined. Thus the 5.65% of organic matter in liquid whey shows that 1000 pounds contain 56.5 lb. of organic solids with an estimated COD of 62.15 lb. and only 1.36 lb. of nitrogen. Therefore, each 1000 lb. of liquid whey would require 1.126 lb. of nitrogen or 5.3 lb. of ammonium sulfate, or 5.5 lb. of 29% ammonia water.

The oxygen requirement for assimilation is 37.5% of the COD [8], hence the 1000 lb. of fluid whey will require 23.3 lb. of oxygen for converting the soluble

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(5) Kountz, R. R. Dairy Waste Treatment Pilot Plant, Proc. 8th Ind. Waste Conf. Purdue Univ. 382-386 (1953).

(6) Webb, B. H. Utilization of Whey in Foods, Food Research 3:233-238 (1938).

(7) Sawyer, C. N., Bacterial Nutrition and Synthesis. In "Biological Treatment of Sewage and Industrial Wastes." Ed. by McCabe, J. and Eckenfelder, W. W., Jr., Vol. I. pp. 3-17. Reinhold Publishing Corp. (1956).

(8) Porges, N., Waste Treatment by Optimal Aeration - Theory and Practice in Dairy Waste Disposal., J. Milk and Food Tech., 19:34-38 (1956).

substance to cell material. Oxygen is also needed for the seed cells. This value omits that used for endogenous respiration. Suitable aeration equipment can be selected on the basis of known oxygen transfer efficiencies of such devices. It must be emphasized that, if at all possible, other means of whey disposal should be selected, since the wet combustion of such a high oxygen demanding material takes considerable power. Dilute wastes can be treated. Conditions for handling more concentrated wastes are being determined.

II. Study for the determination of the effectiveness of spray irrigation as a method for the disposal of dairy plant wastes.

Direct disposal of waste water (its removal from the property without any treatment) is achieved most simply by means of a public sewer system. In order to keep the service charge low, good housekeeping must be maintained in the dairy. Direct disposal is also possible by spray irrigation. Direct disposal should be lower in cost and simpler to operate than a disposal plant.

A cooperative study is underway at the University of Wisconsin "to determine the value of spray irrigation of dairy wastes as a means for their disposal, and to prepare recommendations for the dairy industry on the utility of this method of waste disposal." Two excellent men are associated with us on this project, Dr. Rohlich, Professor of Sanitary Engineering and Dr. Englebert, Professor of Soils. The Wisconsin Committee on Water Pollution has cooperated through Mr. H. N. Kingsbury, a sanitary engineer assigned to industrial waste treatment and pollution abatement. This represents an ideal cooperation between control agencies and research workers.

The "whereas" clauses of the contract mention (a) the need for simpler and more effective methods of disposing of dairy waste to minimize stream pollution; (b) that dairy processing plants are under orders to take measures to prevent such discharge into streams; (c) that aeration processes are generally applicable but reduction of costs in treatment is still needed; (d) that spray irrigation may be economical and practical if land of the correct soil characteristics is available; (e) that spray irrigation of waste may increase the value of the land; (f) that the method may be used as an alternative to, or in conjunction with, the rapid aeration process; (g) that spray irrigation systems have been successful and unsuccessful; (h) that scientific and technical data are required; and (i) that basic information shall be obtained under actual operating conditions.

The contract states that the contractor is to plan and diligently conduct studies designed to evaluate the usefulness of spray irrigation as a method for the disposal of dairy plant wastes. These investigations are to be conducted to develop information to permit efficient use of spray irrigation. Factors to be studied include chemical composition of wastes, pre-treatment and irrigation facilities, types of cover crops, chemical composition of water utilized, soil characteristics, topography and climatic conditions.

A large number of the milk plants in Southwestern Wisconsin were visited. (Approximately 71 food processing plants in that state were using spray type irrigation for waste disposal by January 1, 1956.) The cooperation of the Committee on Water Pollution was enlisted since that group has a record of dairies that were installed or were installing spray irrigation. Finally five cheese factories and one complete dairy were selected for study.

At each site a topographic survey of the area under irrigation has been made. These initial surveys were conducted before irrigation was begun. Soil borings to a depth of four feet and observations of the topography were made and showed a variety of conditions. One site is a well-drained calareous forest soil with dense subsoil; another is an alluvial deposit of sandy loam with permeable top and subsoil; a third is silt loam covering sandstone; a fourth lies along a stream only a few feet above the water level and gives indications of water logging, a fifth site is shallow soil overlying impermeable rock, the sixth is presently under examination.

The manager at each plant takes an active part in recording temperature, pumping time and weather observations. He also makes changes in piping which are recorded on a map of his field and maintains a check list of plant operations. In addition, specially designed flow measuring and sampling devices are in operation. Samples are collected alternately by two graduate students at frequent intervals. Intensive tests are being made on each sample.

It is too soon to draw any conclusions, but the data will be of tremendous value. As far as is known, this will be the first time that effects of spray irrigation of dairy wastes on soil will be followed from the very initiation of such treatment. Any changes in organic matter, solids, nitrogen, sodium, chlorides and other ions will be apparent and the effect of the waste in the soil will be followed. It is believed that from these studies will come interesting and applicable observations.

Greater details on this project will probably be given at the Purdue Conference by Dr. Rohlich.

III. The development of practical biological methods for the production of feed supplements and other useful products from cheese whey.

The search is still continuing to develop practical methods for utilization of the almost 8.9 billion lb. of liquid whey now wasted each year. This amount of liquid whey contains about 565 million lb. of solids which is potentially available for processing. Many substances have been obtained by the fermentation of whey. Among these are lactic acid, riboflavin, yeast, ethyl alcohol, vinegar, butanol and acetone. Butyric, citric and propionic acids have been reported as well as Vitamin B_{12}.

Practically all processes that convert whey by microbiological processes have been discontinued for economic reasons. We are directing fermentation studies toward the development of more efficient means of converting whey to a needed product or new products of potential value. This will be accomplished by selection of desirable microorganisms and establishing conditions of maximum yield.

Currently we are studying the conversion of whey by yeast and are examining this fermentation carefully. The economic conversion of whey solubles to cells would lead to an easily recoverable product of value as a feed supplement. Yeast, fungi and bacteria are such convertors. The best conditions must be established.

Newer information on nitrogen and phosphorus supplementation and oxygen requirements of cells will be of value and may result in more efficient use of equipment or increased yields that may make a process feasible.